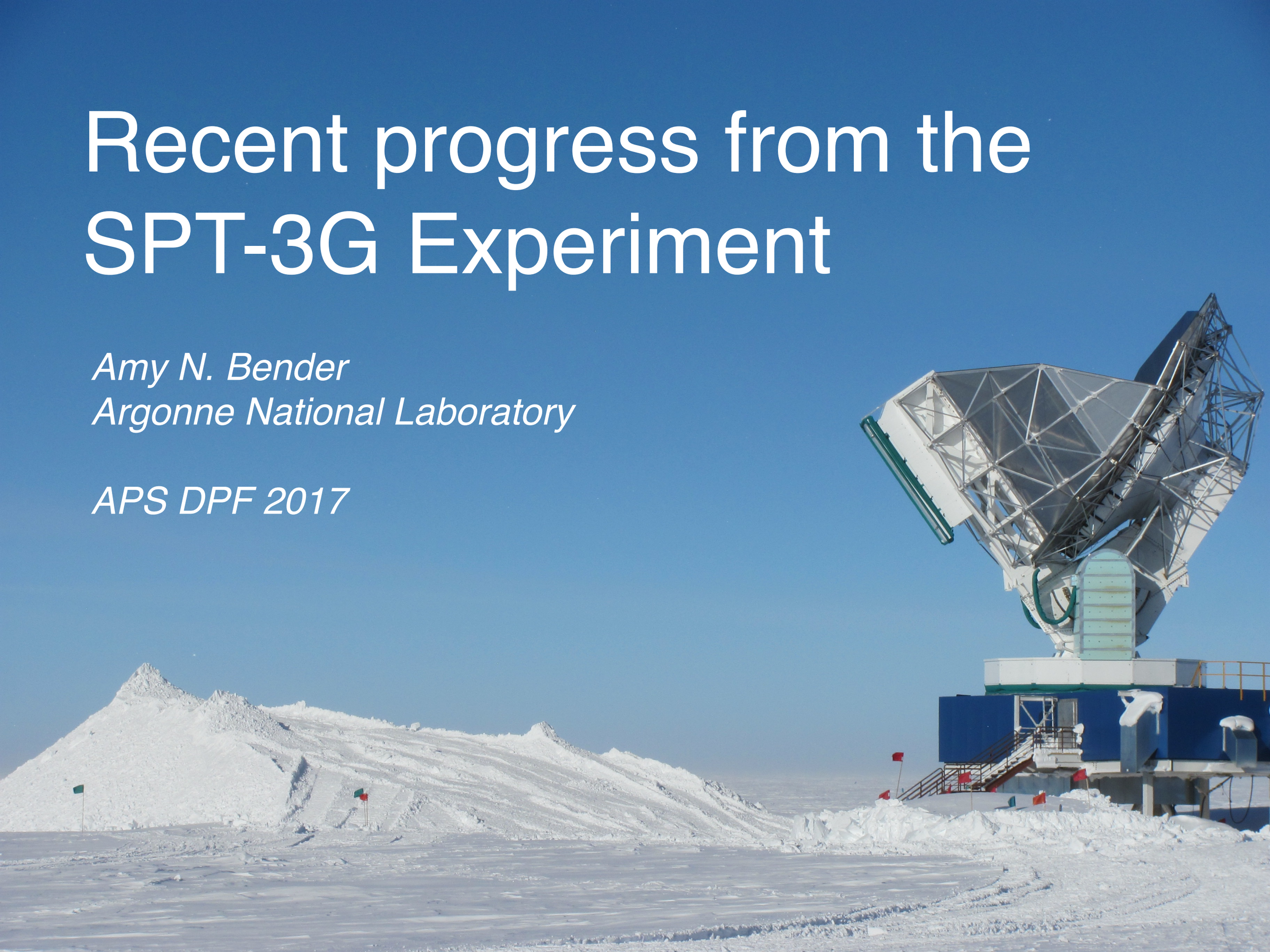
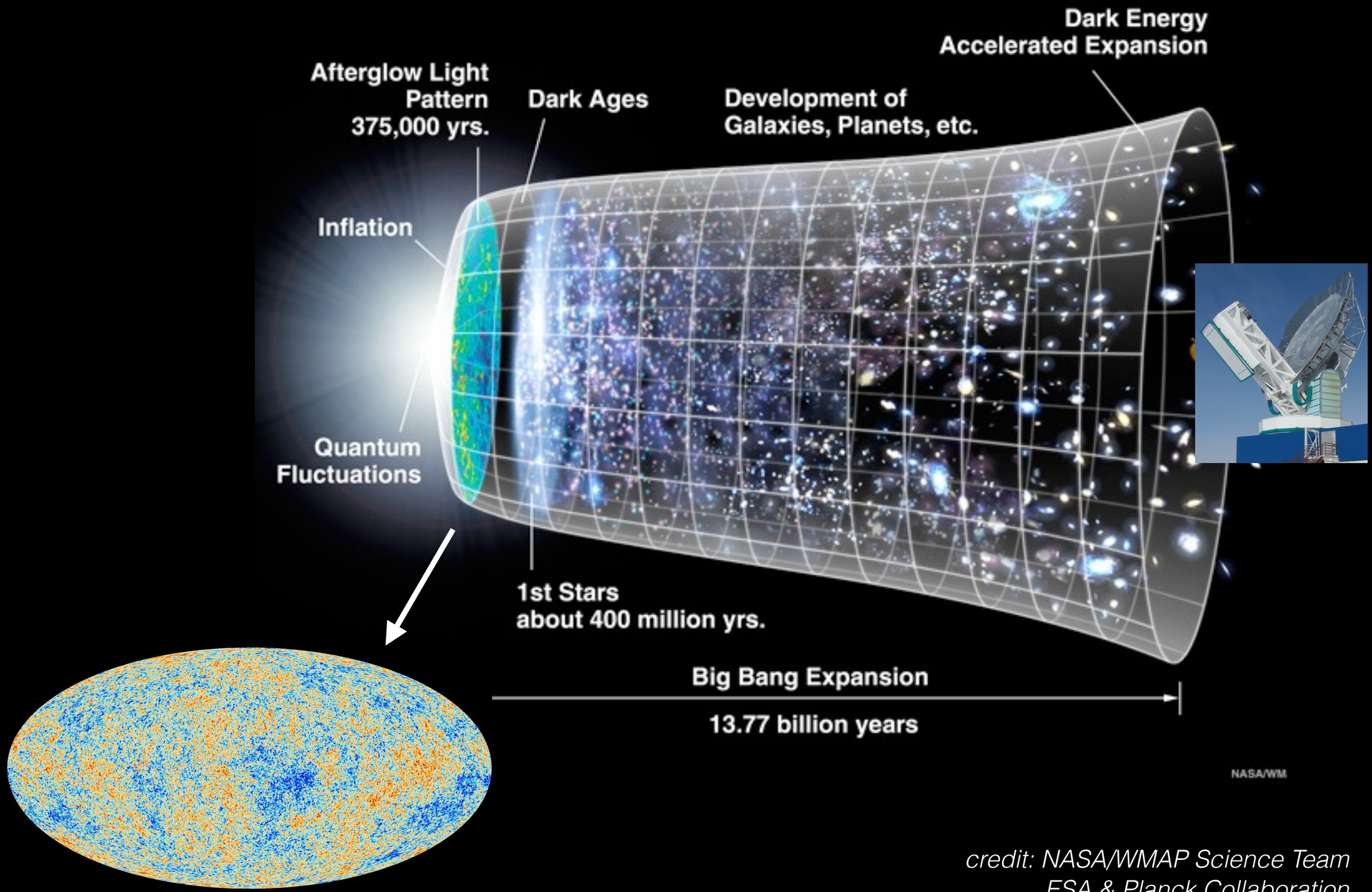
# Recent progress from the SPT-3G Experiment

*Amy N. Bender*
*Argonne National Laboratory*

*APS DPF 2017*



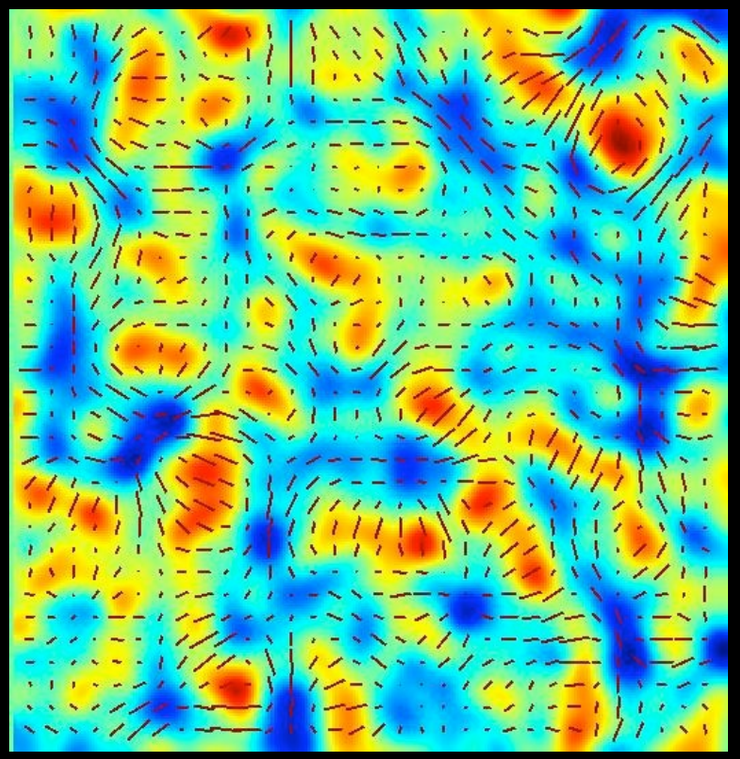
# The History of Everything

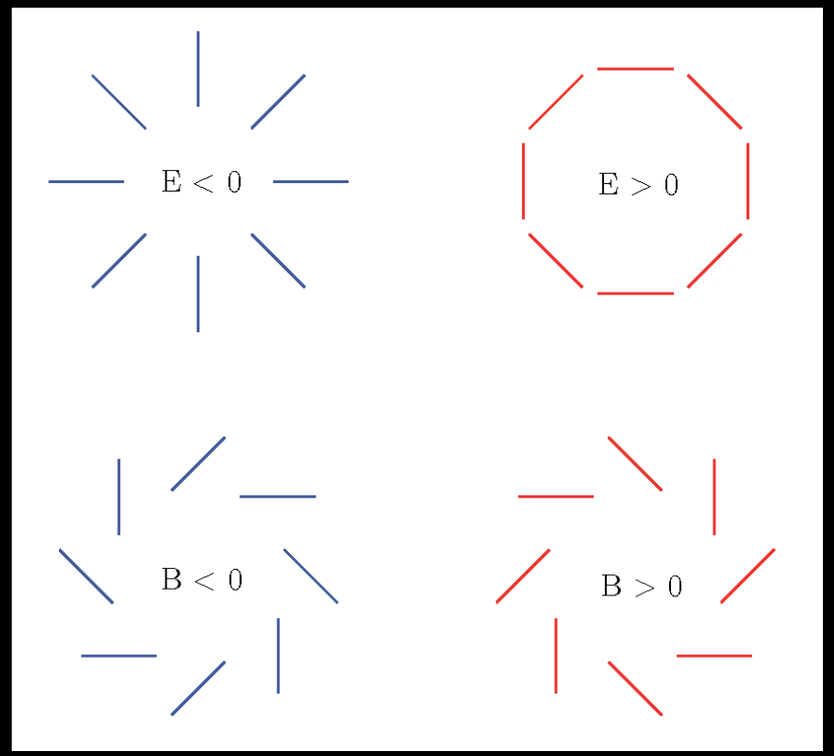



*credit: NASA/WMAP Science Team*
*ESA & Planck Collaboration*

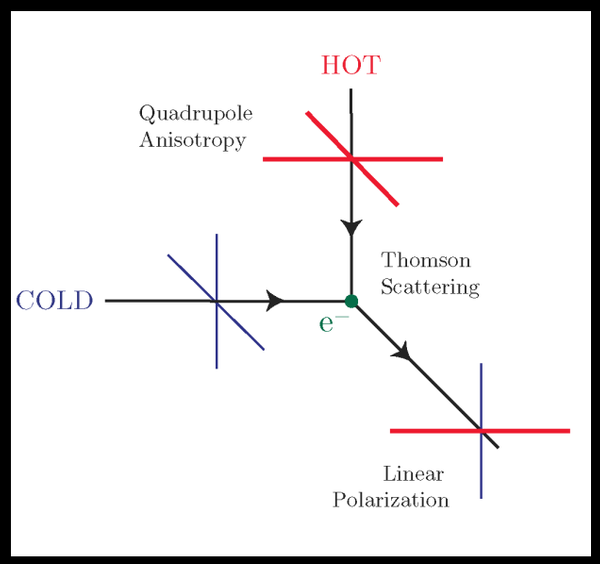
# CMB Polarization

*Seljak & Zaldarriaga 1998*



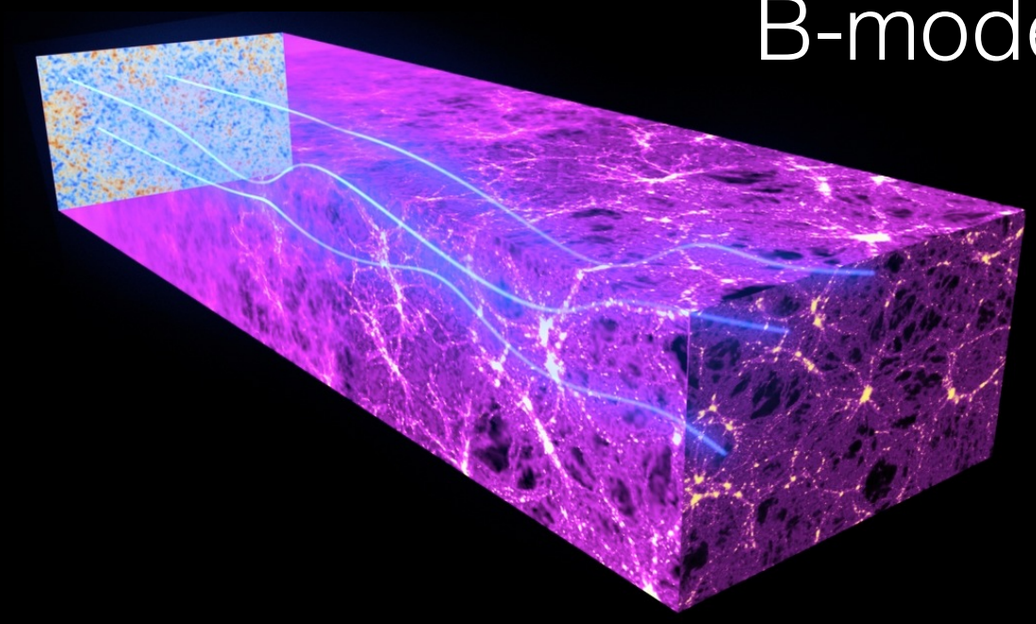



E-modes




*Baumann 2009*

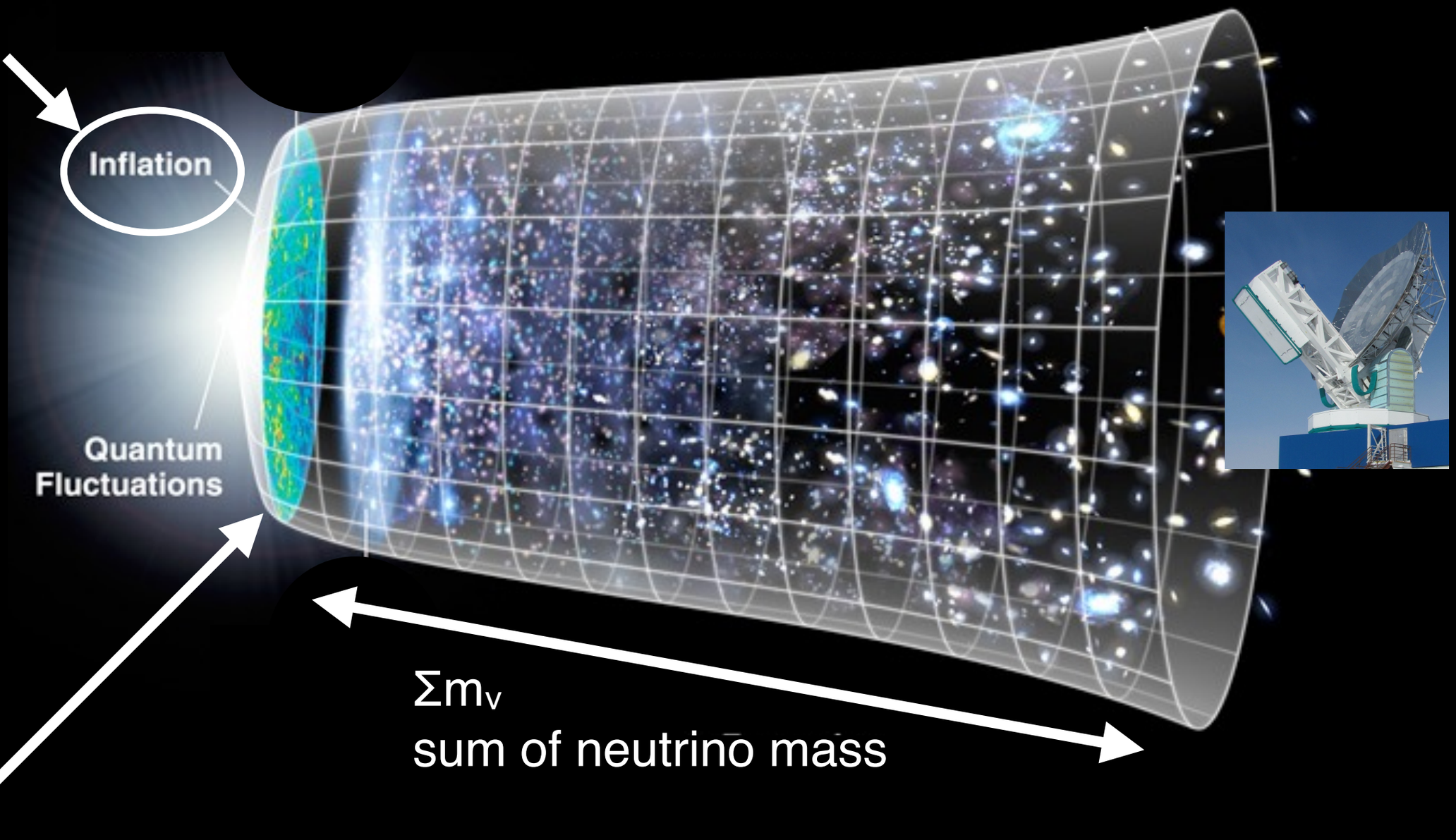
B-modes



*credit: ESA and the Planck Collaboration*

# The Universe as a Laboratory

r: tensor to scalar ratio

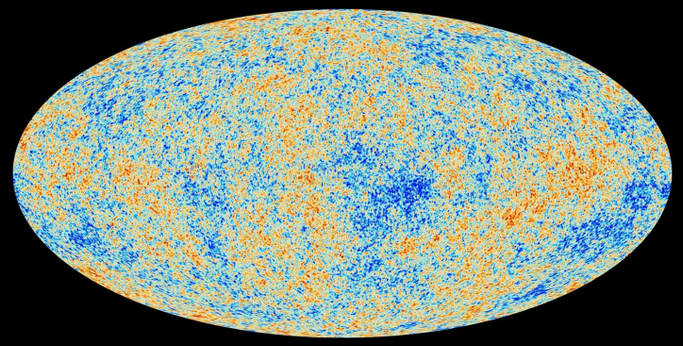


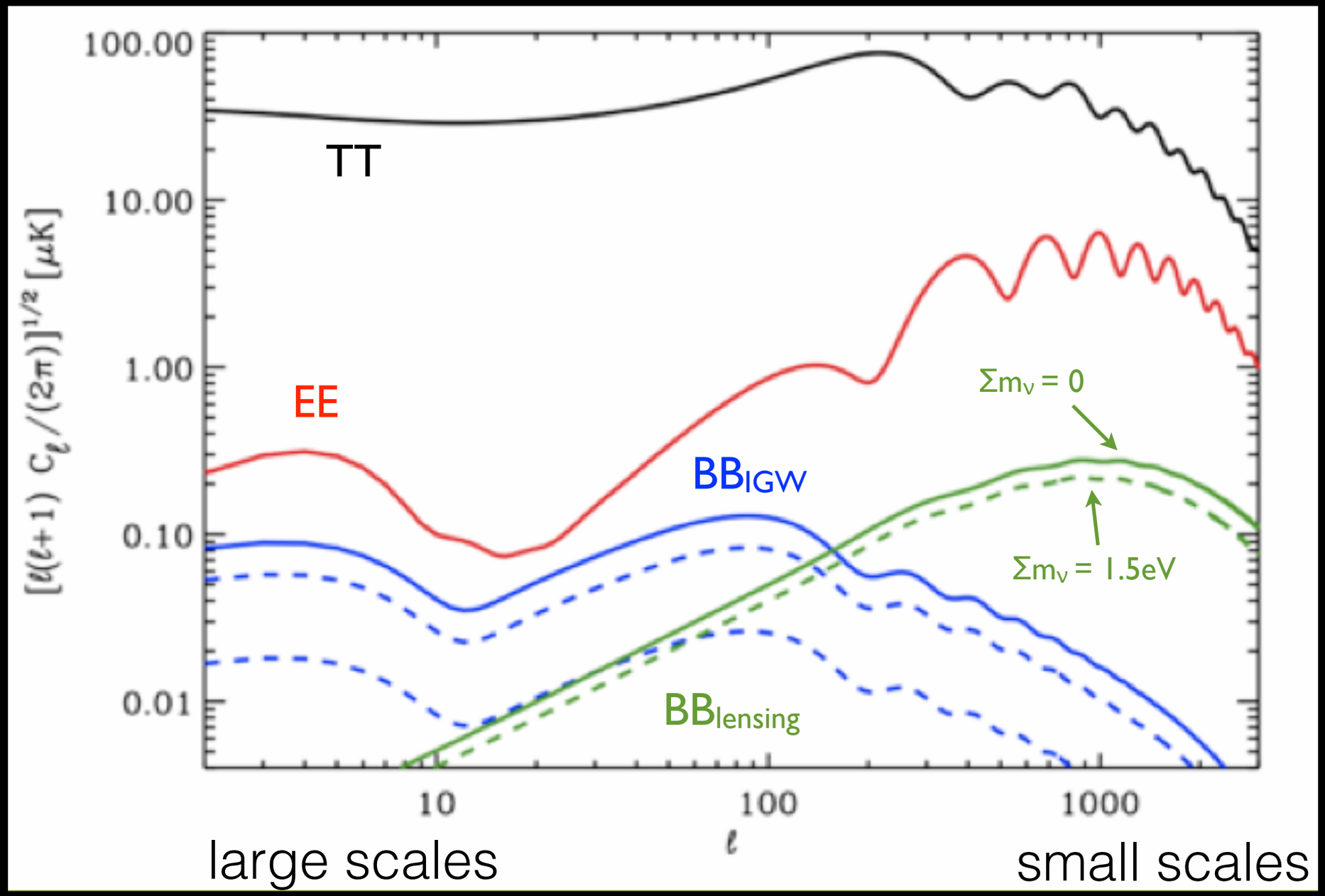

$\Sigma m_\nu$
sum of neutrino mass

$N_{eff}$:
effective number of neutrino species

*credit: NASA/WMAP Science Team*

# CMB Power Spectra

FFT (  ) →




large scales

small scales

# The SPT-3G Collaboration


Argonne NATIONAL LABORATORY

BERKELEY LAB

NIST

Fermilab

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

KICP
Kavli Institute
for Cosmological Physics
AT THE UNIVERSITY OF CHICAGO

Berkeley
University of California

Case
CASE WESTERN
RESERVE UNIVERSITY

McGill

Colorado
University of Colorado at Boulder

THE UNIVERSITY OF CHICAGO

LMU
LUDWIG-
MAXIMILIANS-
UNIVERSITÄT
MÜNCHEN

Harvard-Smithsonian
Center for Astrophysics

UCDAVIS
UNIVERSITY OF CALIFORNIA

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Funded By:

NATIONAL SCIENCE FOUNDATION

U.S. DEPARTMENT OF
ENERGY

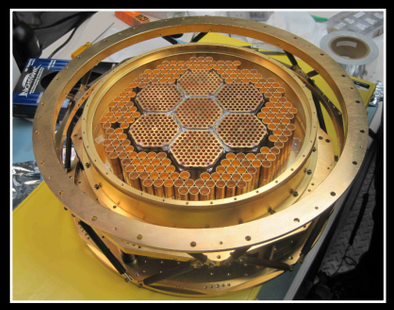
# The South Pole Telescope (SPT)

10-meter sub-mm quality wavelength telescope

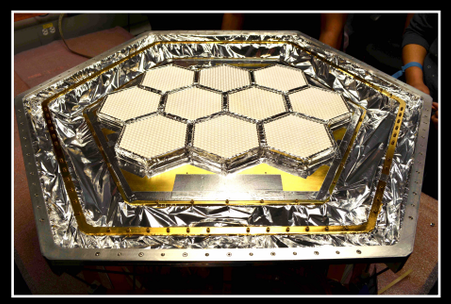
**95**, **150**, **220** GHz and
**1.6**, **1.2**, **1.0** arcmin resolution

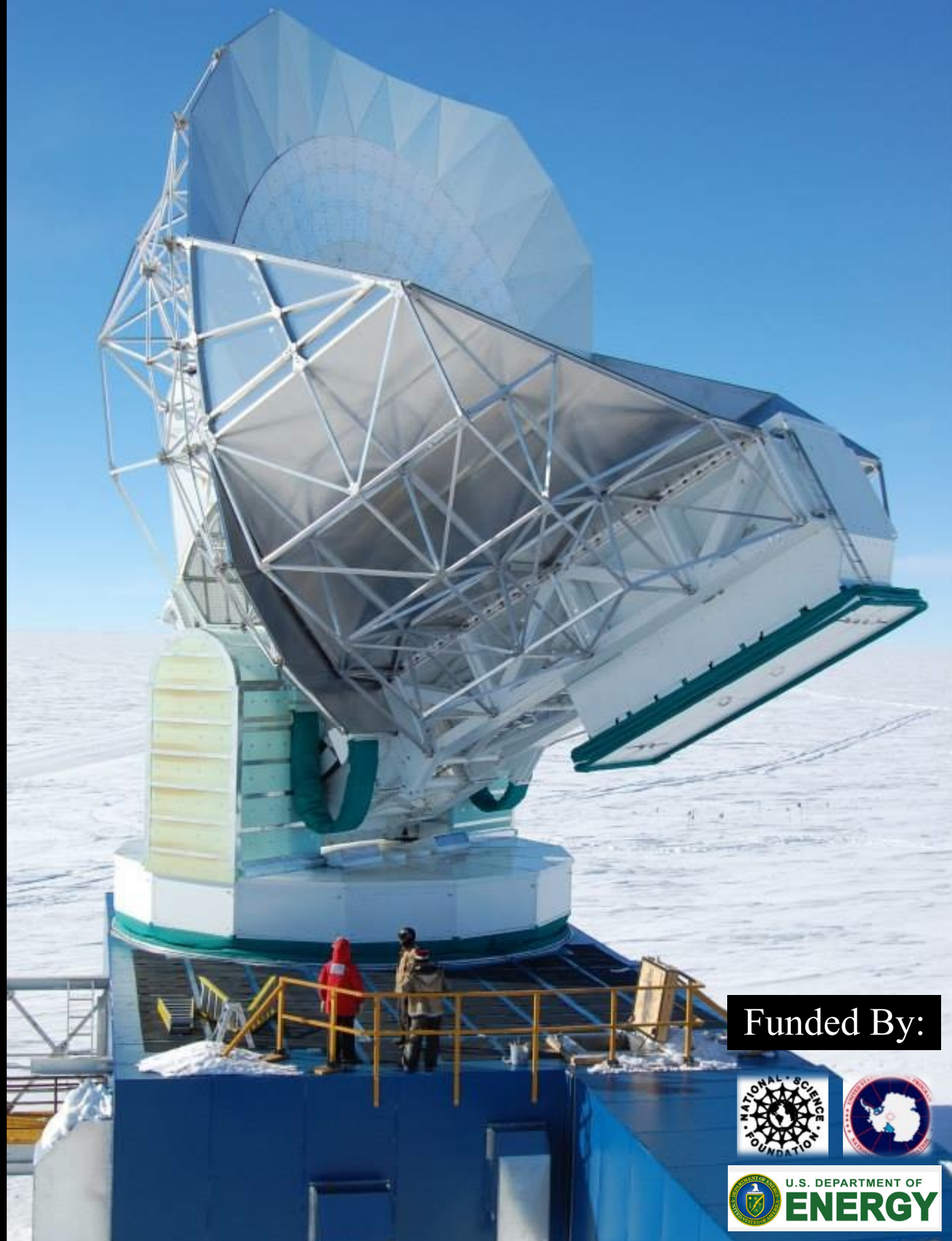
**2007: SPT-SZ**
960 detectors
95,150,220 GHz

**2012: SPTpol**
1600 detectors
95,150 GHz
***+Polarization***



**2017: SPT-3G**
~16,000 detectors
95,150,220 GHz
***+Polarization***





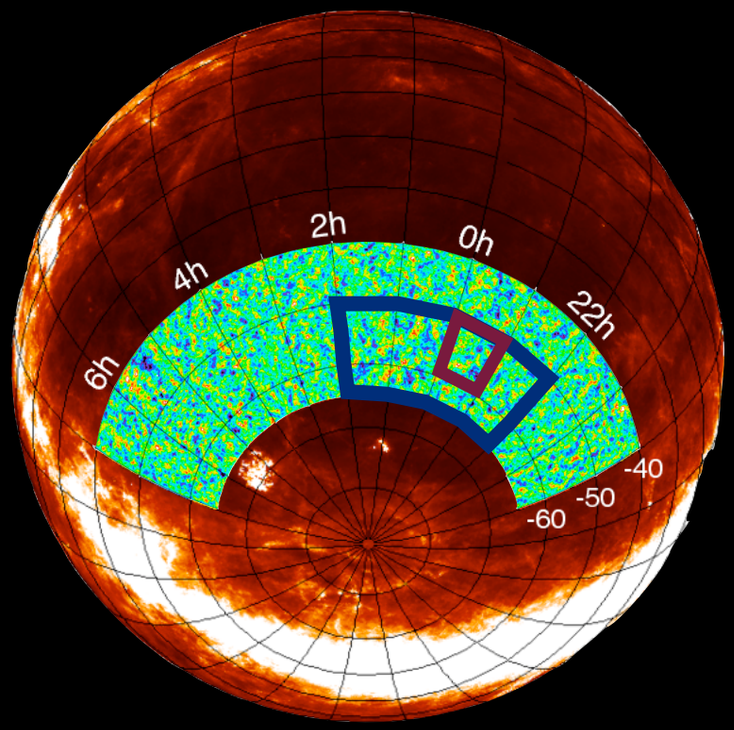
Funded By:

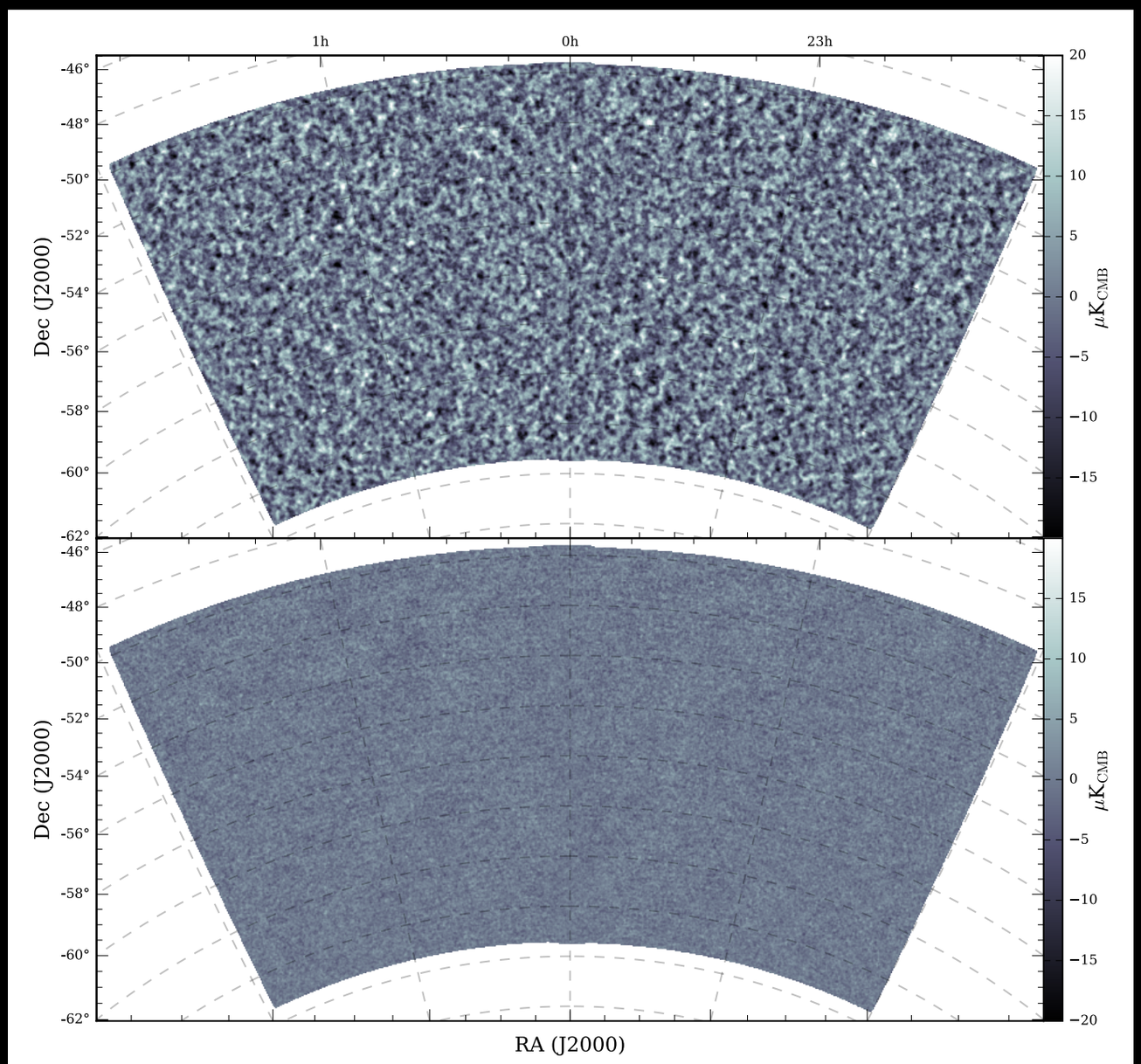
National Science Foundation

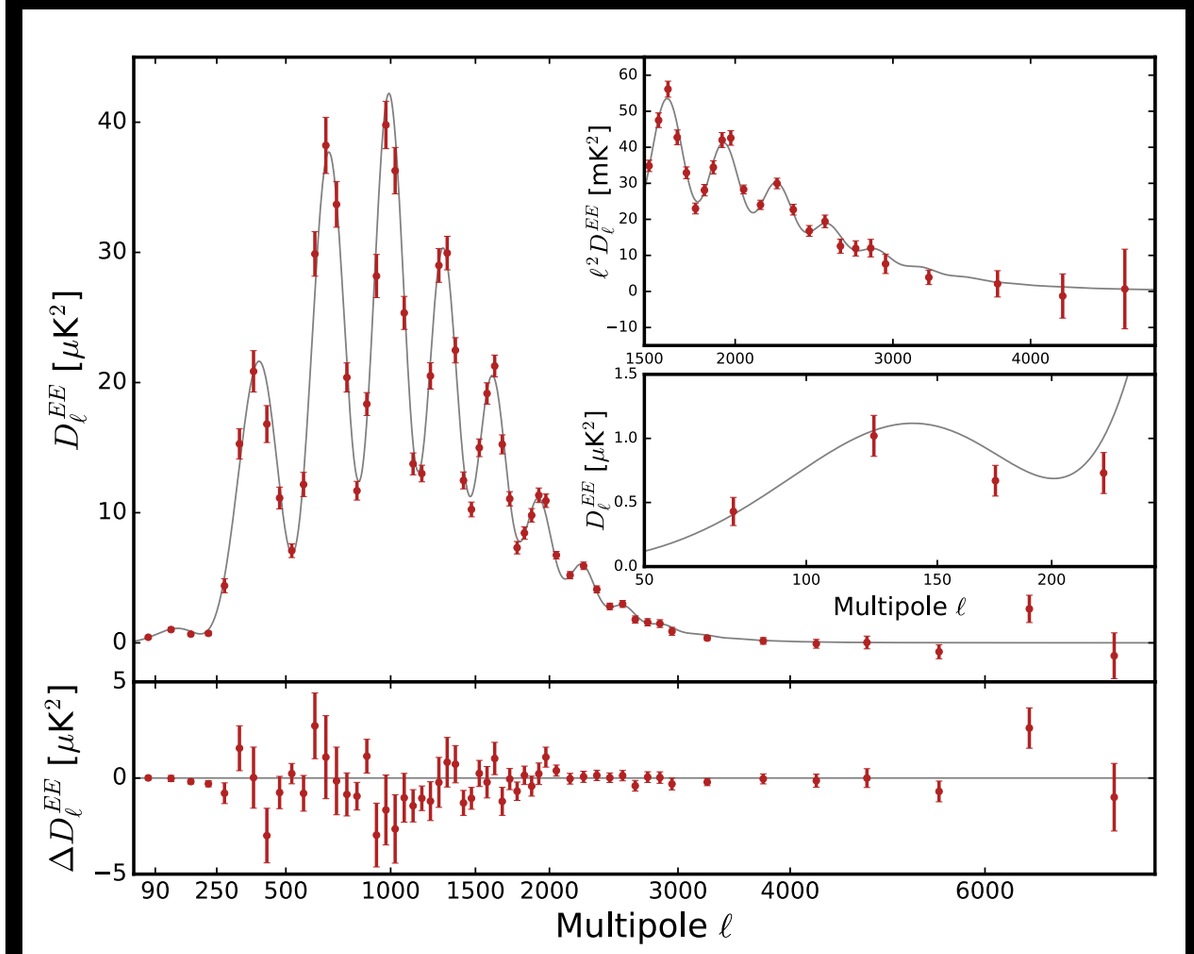
U.S. Department of Energy

# SPTpol EE Power Spectra

## Henning 2017: arXiv1707.09353v1



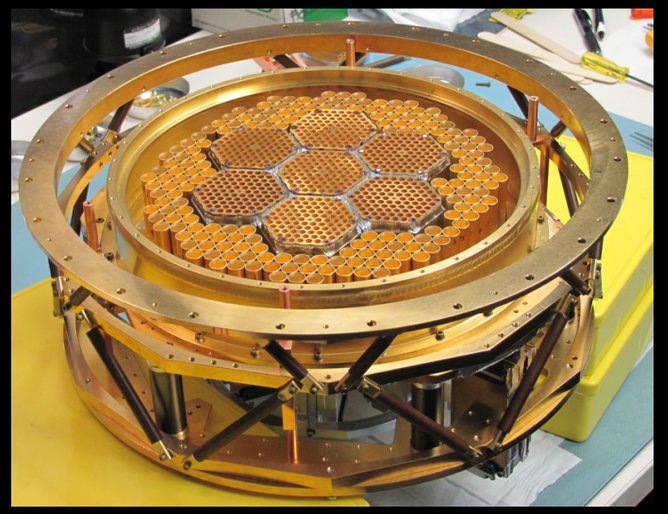



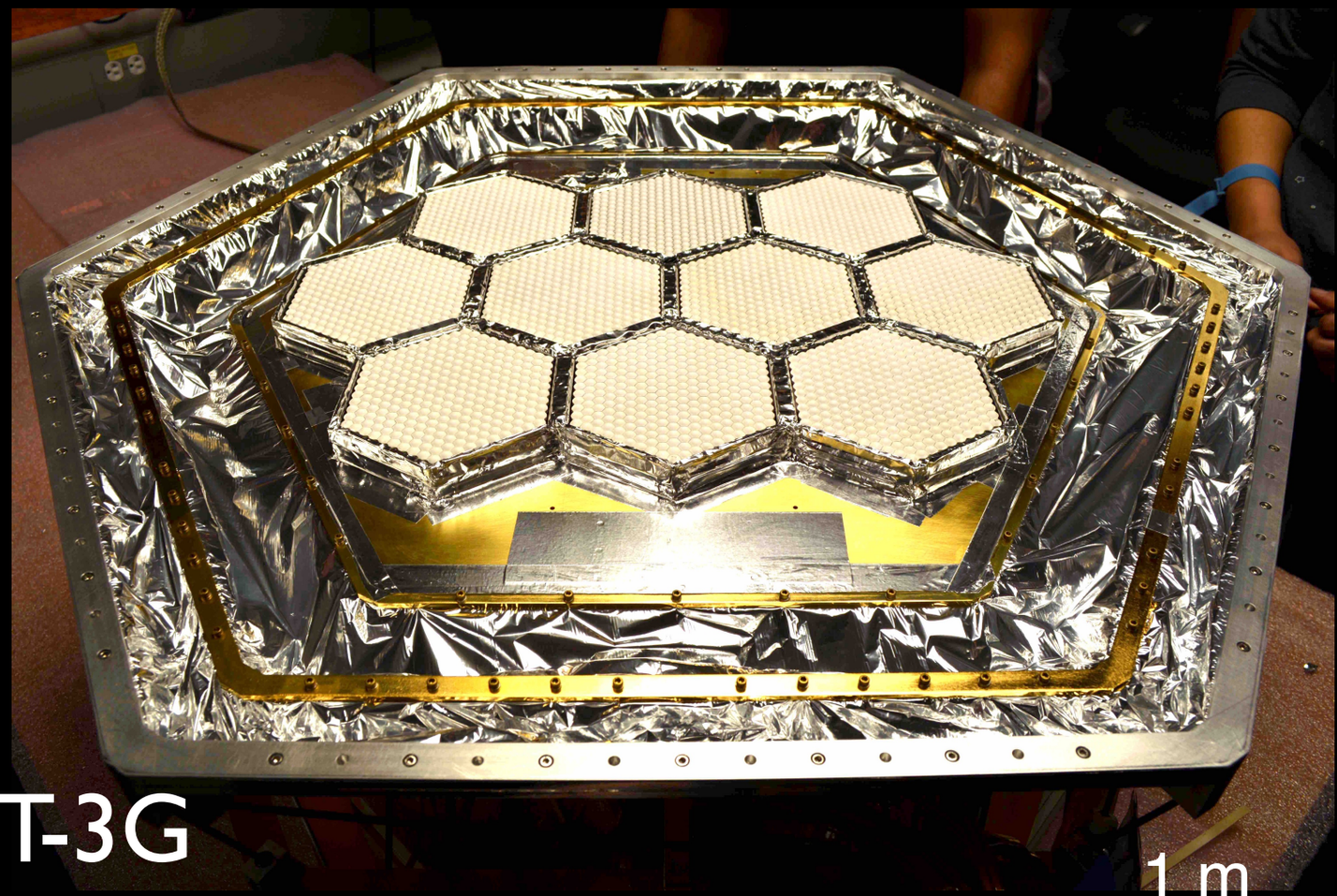
# Scaling Up for SPT-3G

- SPT uses transition-edge sensor bolometers
  - Noise is dominated by the incoming photon noise
  - More sensitivity requires more detectors
- Technological Challenges
  - Detector fabrication
  - Detector readout
  - Cryogenics
  - Large optical elements

SPTpol

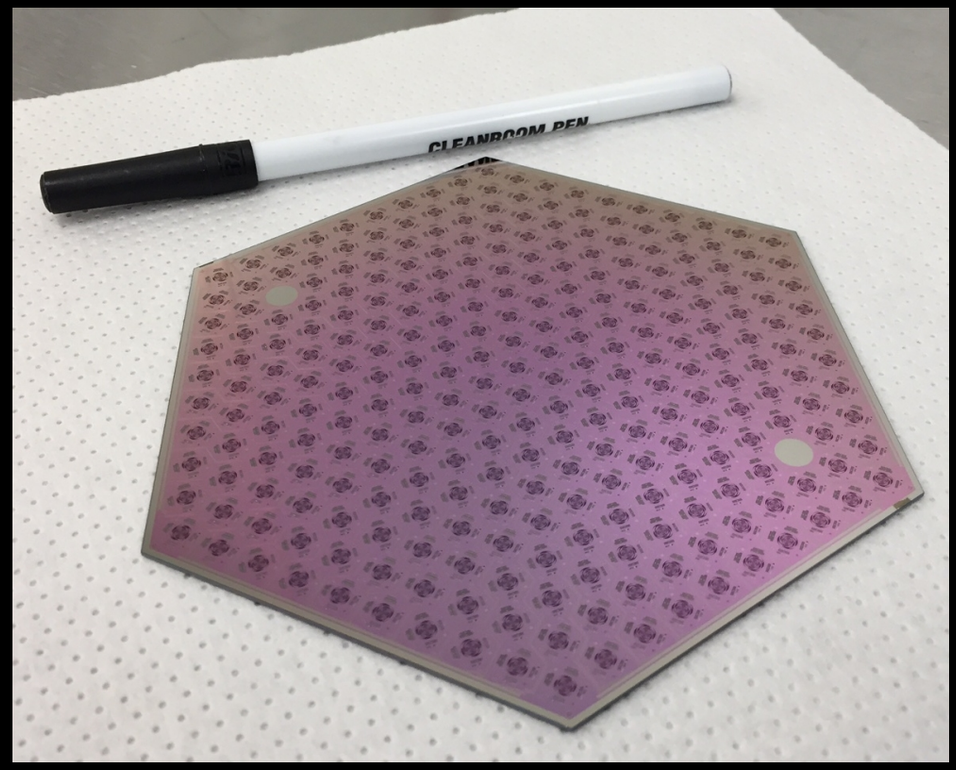


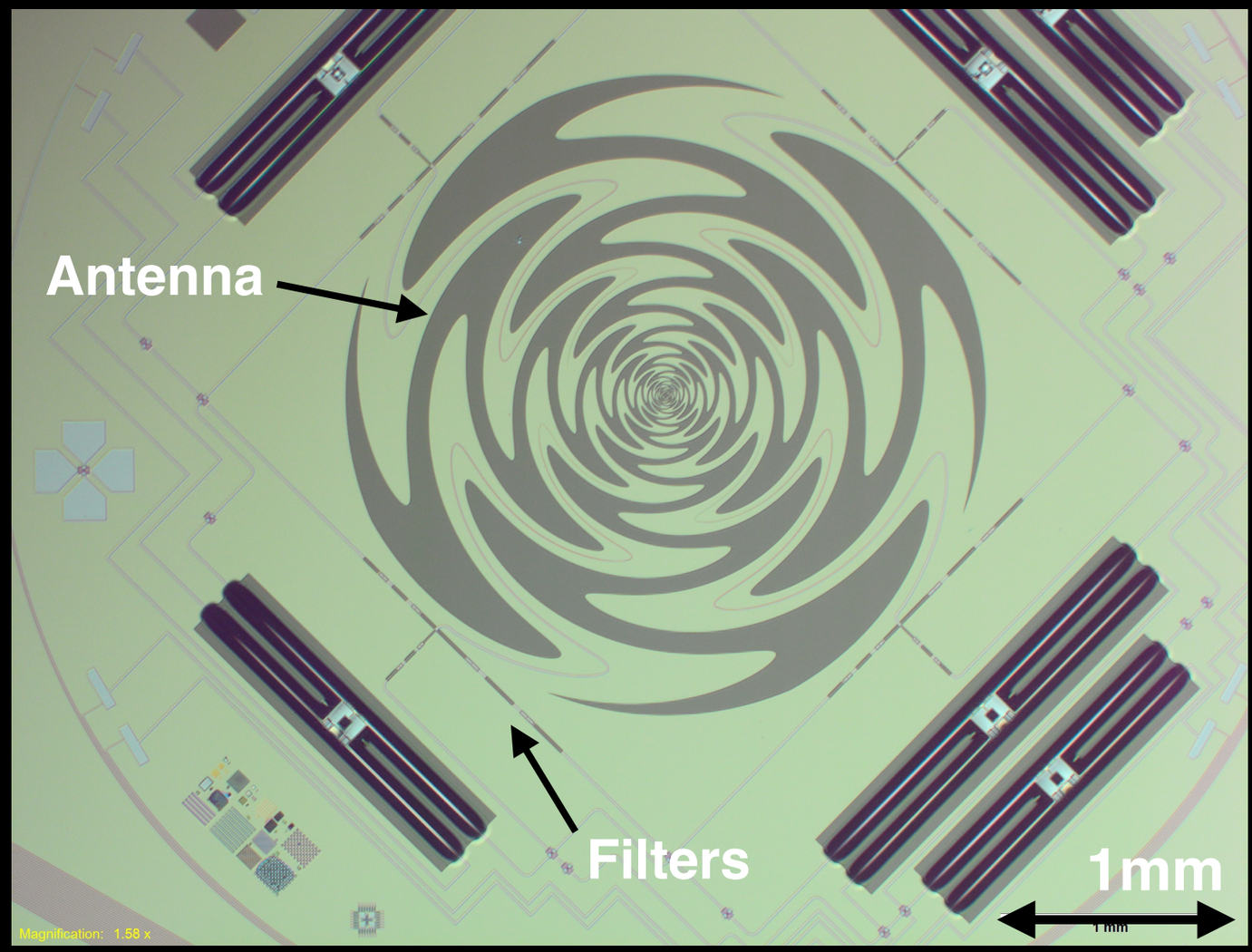
Relative Scale Accurate



# TES Detectors

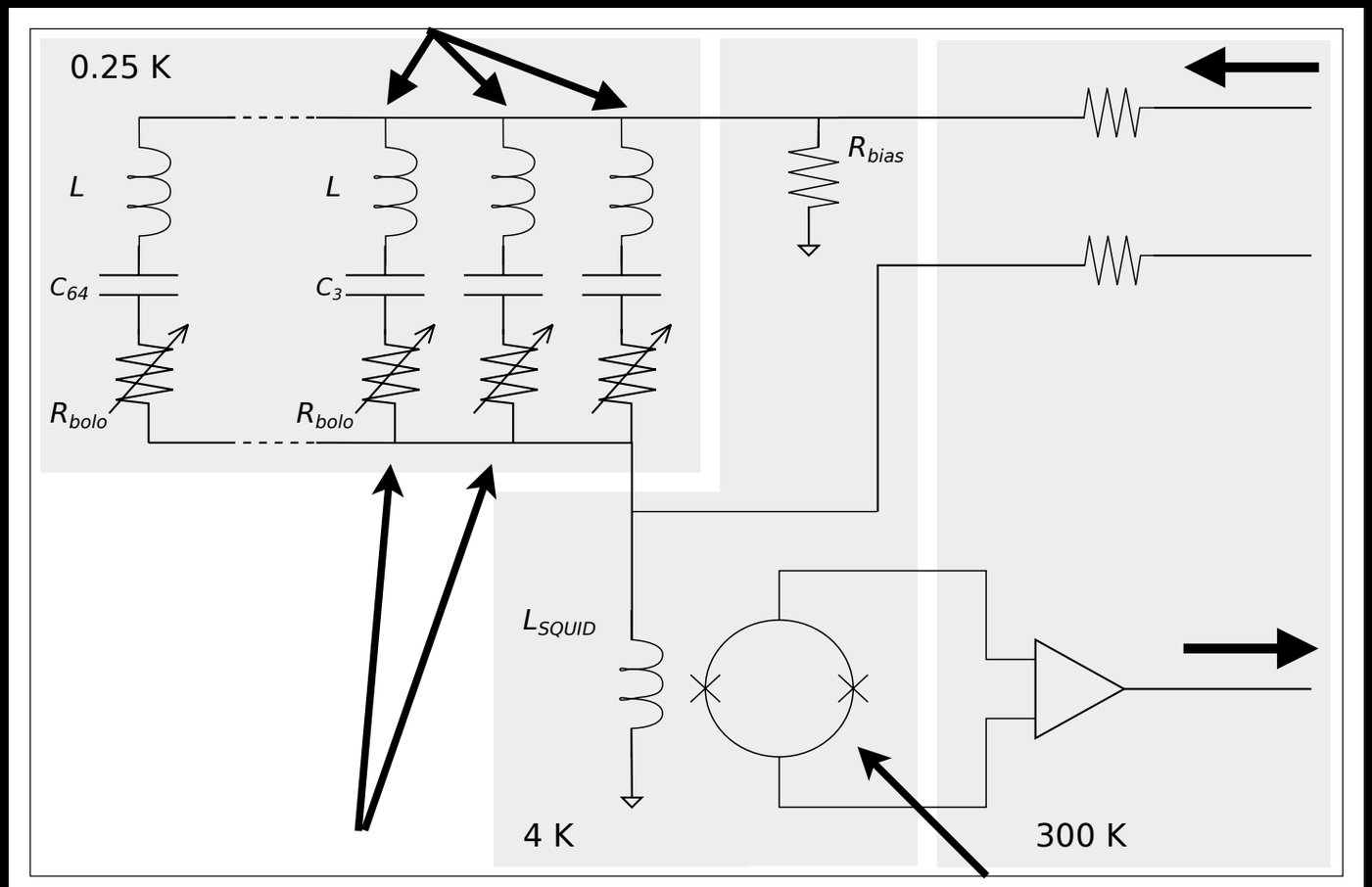
- Broad-band sinuous antenna coupled via microstrip and in-line filters to TES bolometers
  - 6 separate TES islands per pixel  (3 bands & 2 polarizations)
    - 271 pixels fabricated monolithically on a  6” wafer
- Fabricated at Argonne National Laboratory
- 10 wafer x 271 pixels x 6 TES ~ 16,000 detectors



# Multiplexing Readout

## LC Filters



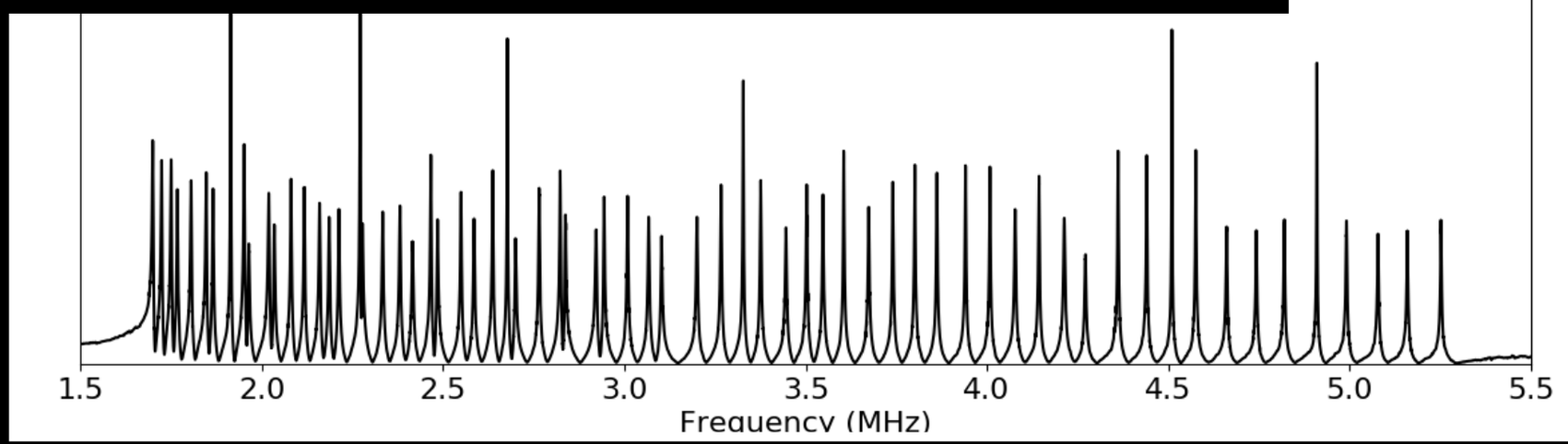

AC Bias

64 TESs read out on single pair of wires.

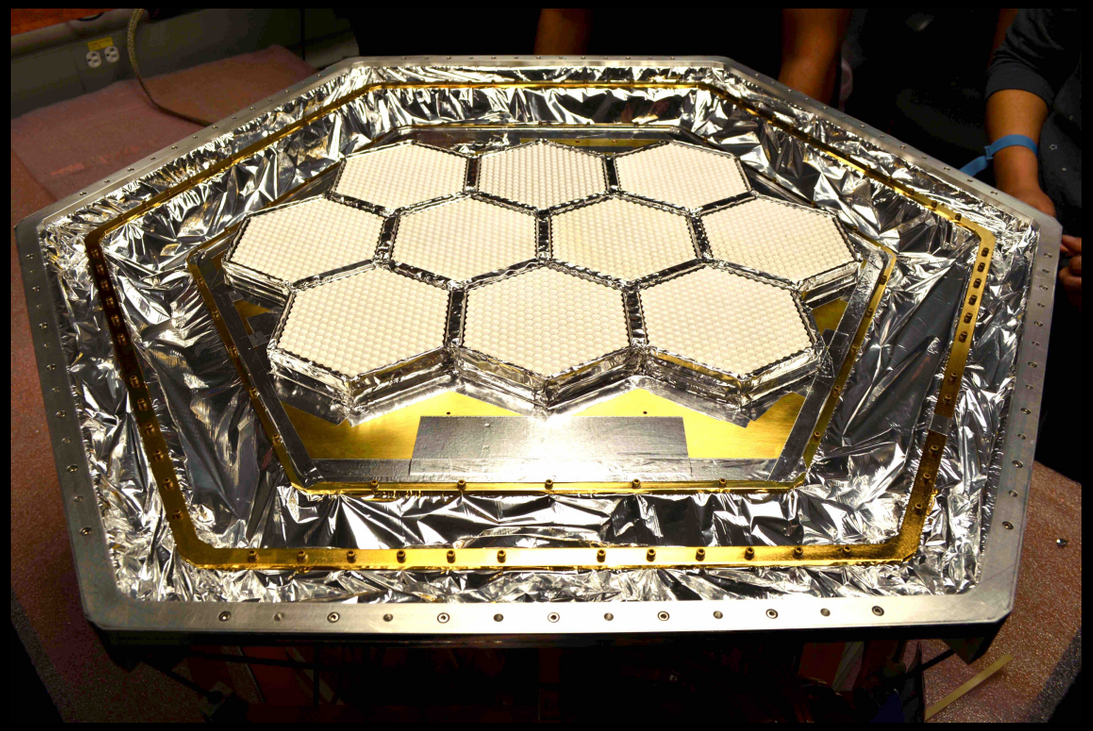
Demodulation & Feedback

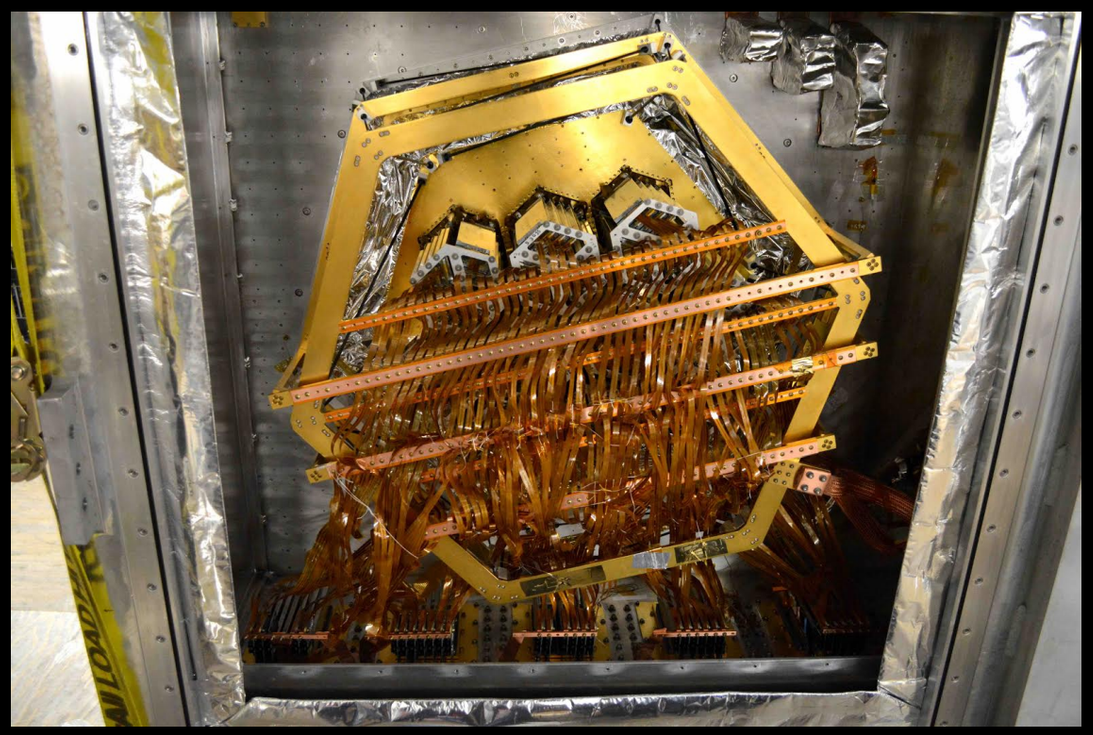
TES Bolometers

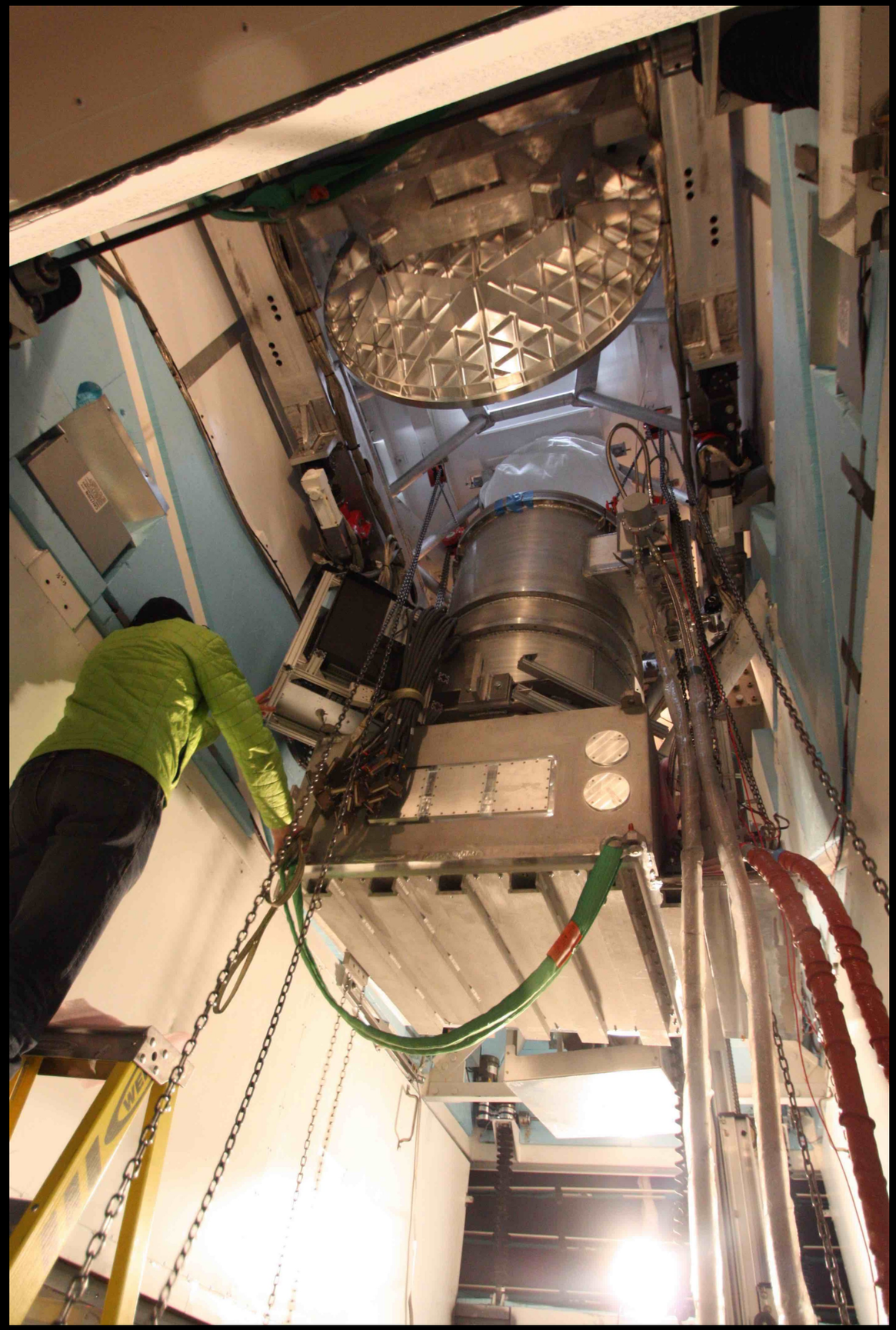
SQUID Amplifier



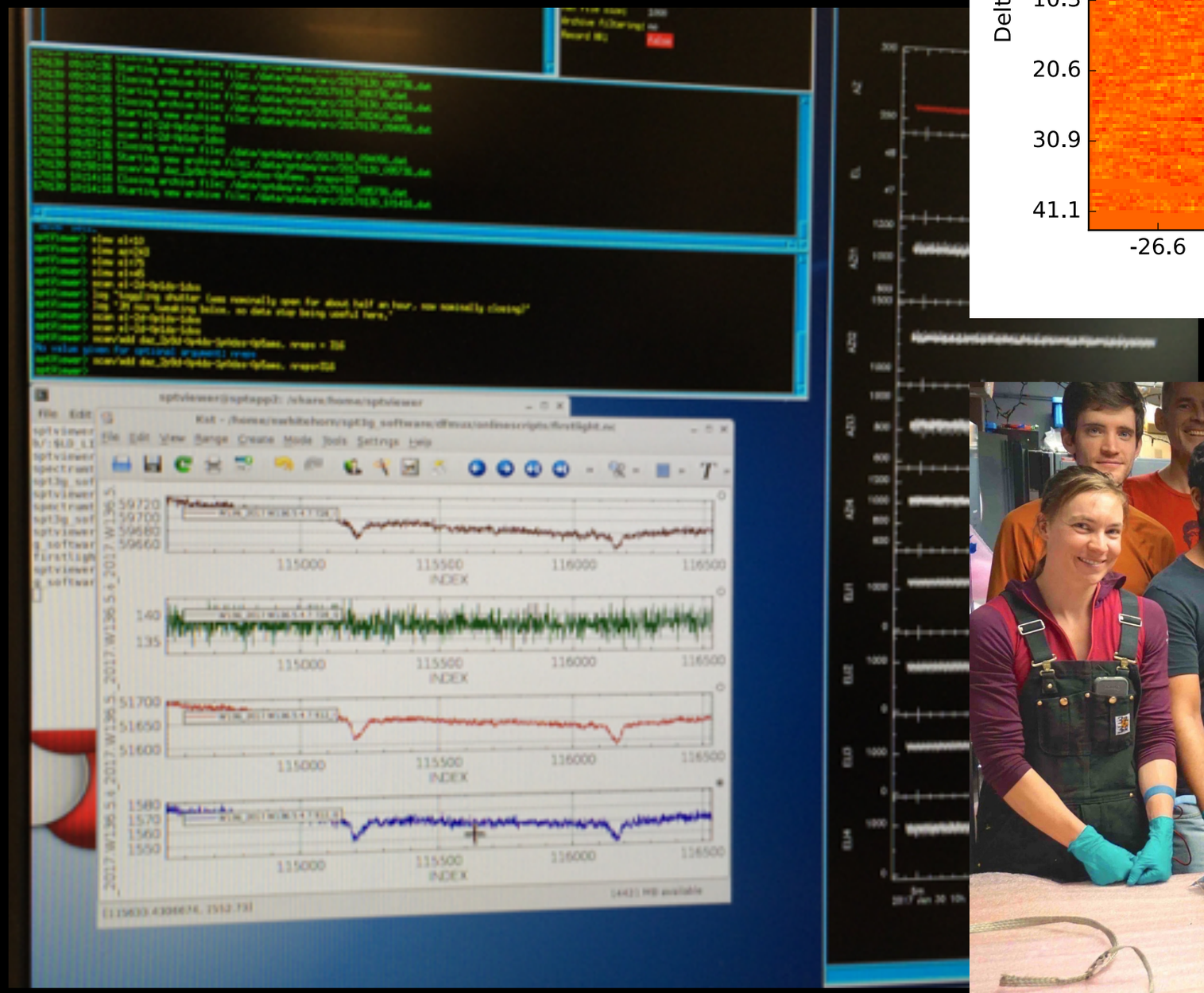
# Integration

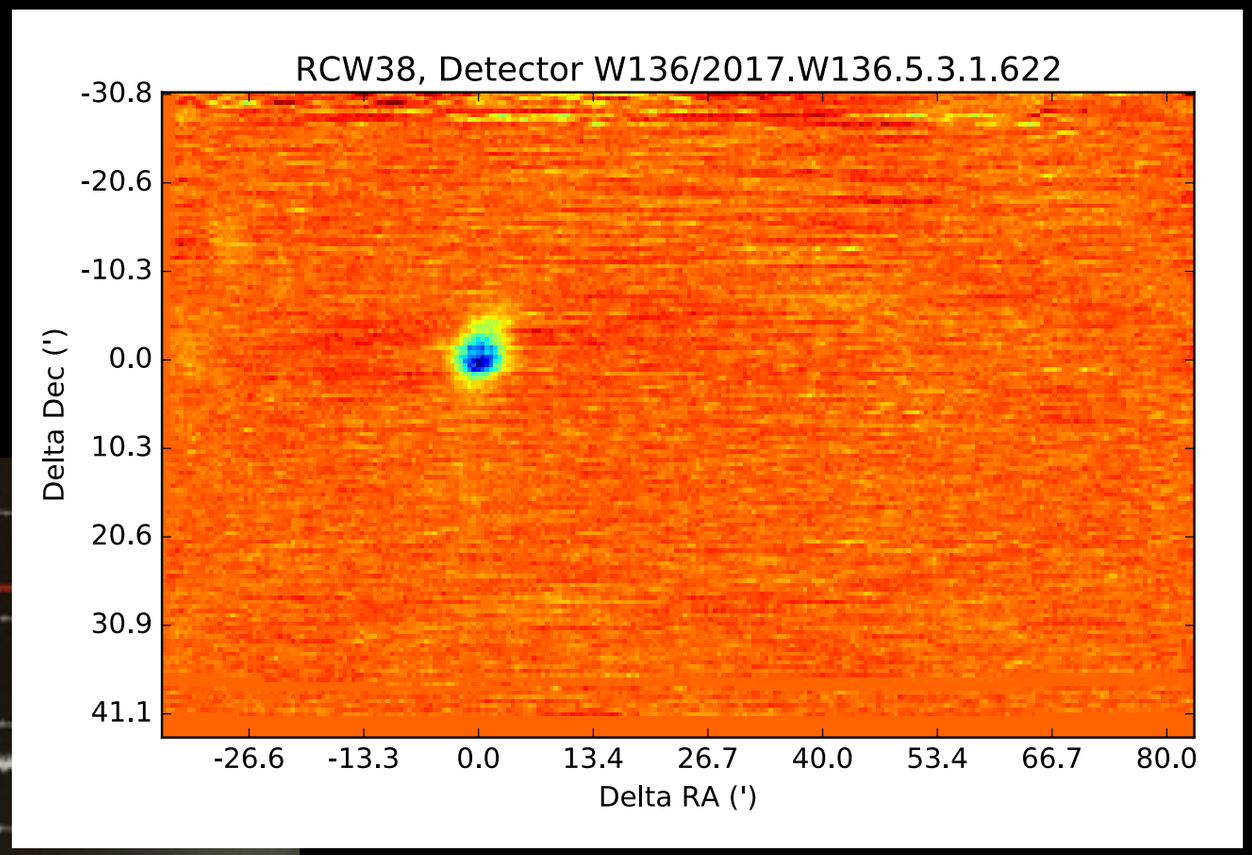


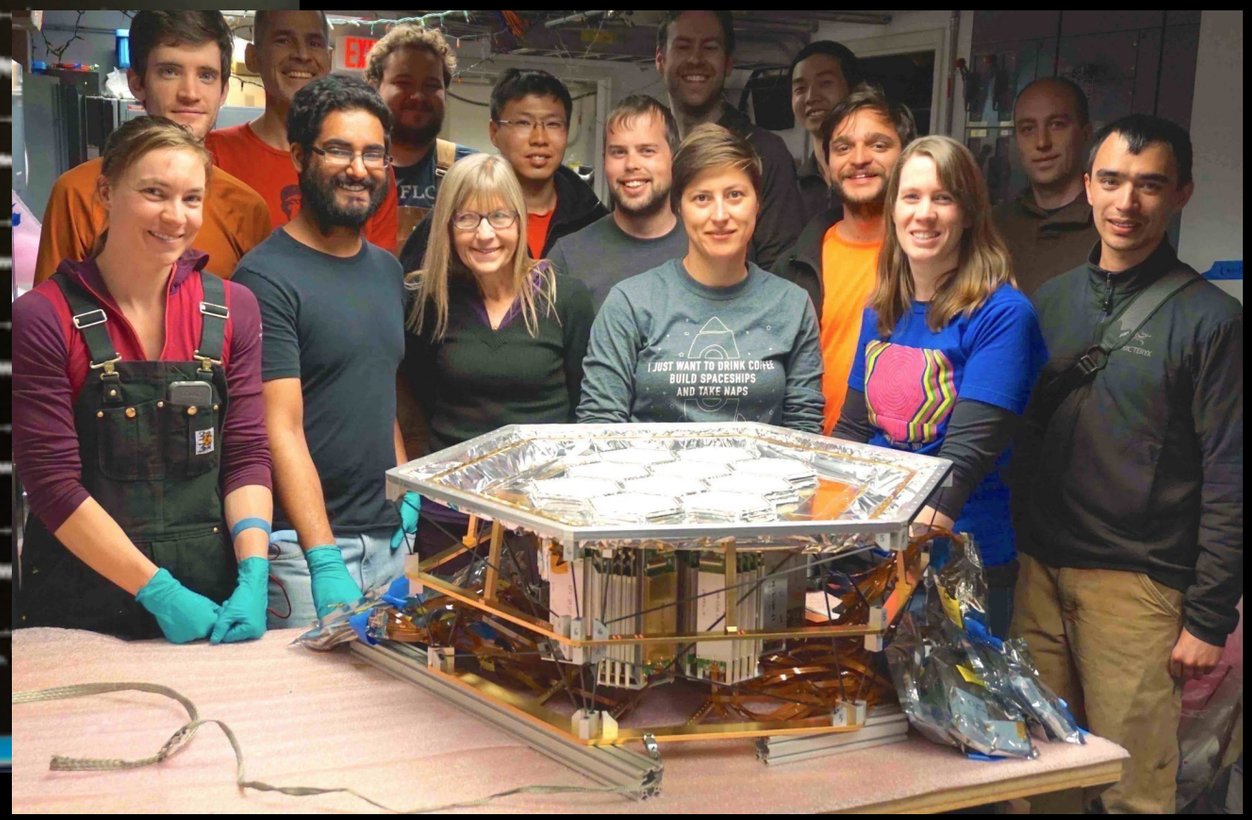




# SPT-3G First Light
# January 30, 2017





# Current Receiver Status

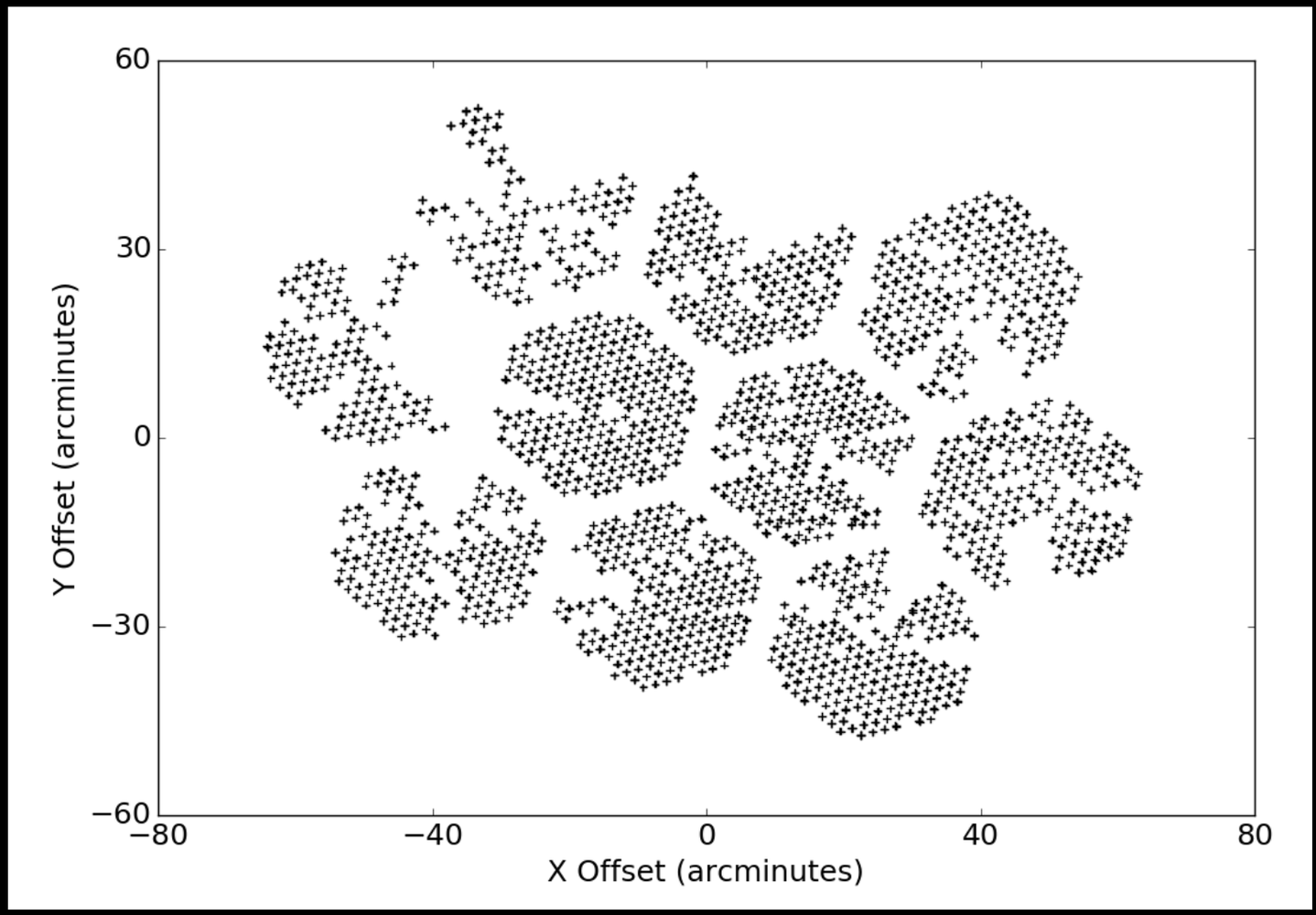
Instrumental Sensitivity ~ $N_{bolometers}$

**Detector Yield ~ 74%**

Main Losses:

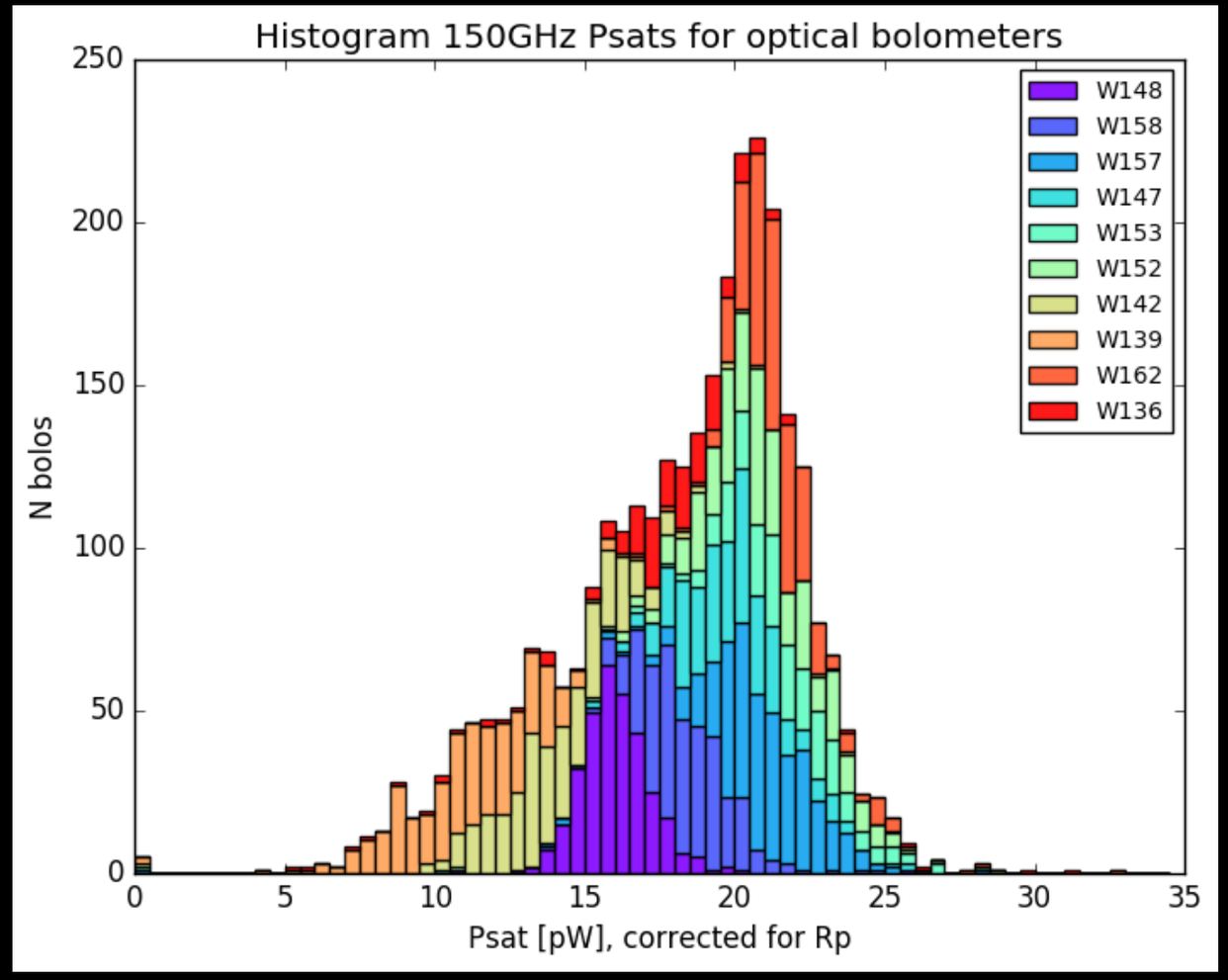
- Detector defects (~11%)
- Readout defects (~12%)
- Experimental Readout (~3%)

December 2017 receiver work planned to recover these losses.



# Noise

- Noise is enhanced compared to expectation
  - Due to subtle effect in SQUID amplifiers
  - Replacement amplifiers will enable nominal performance

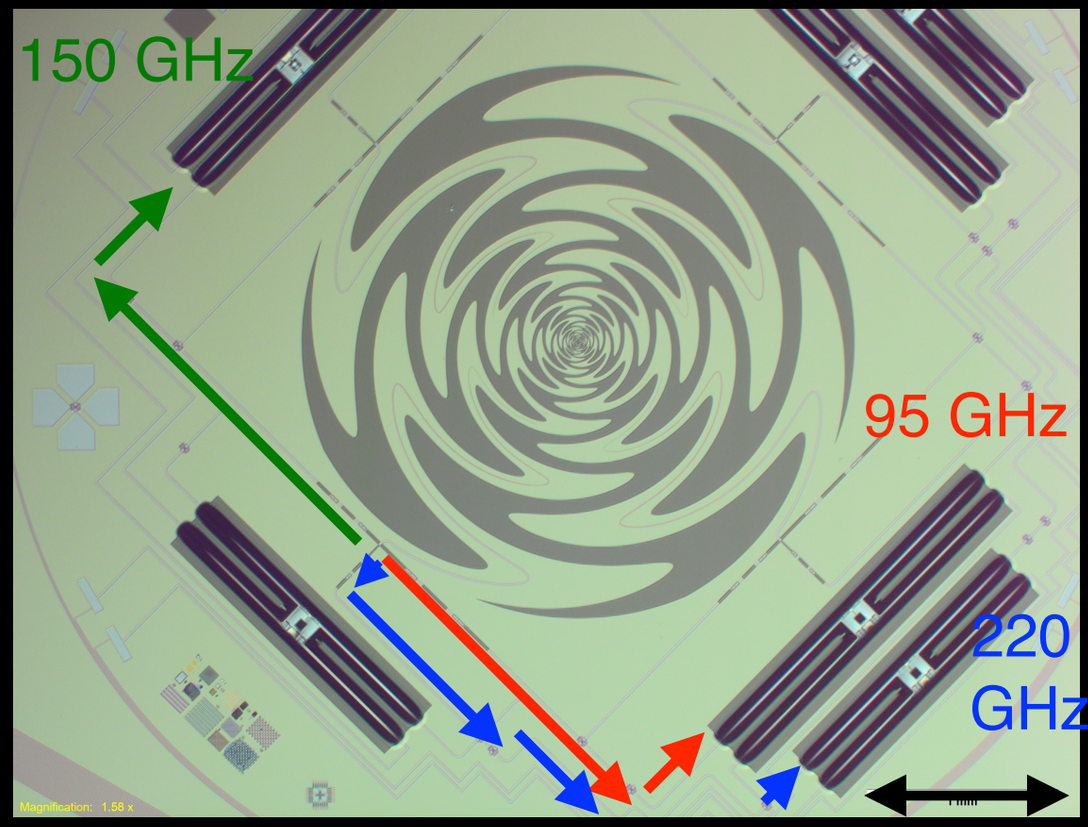


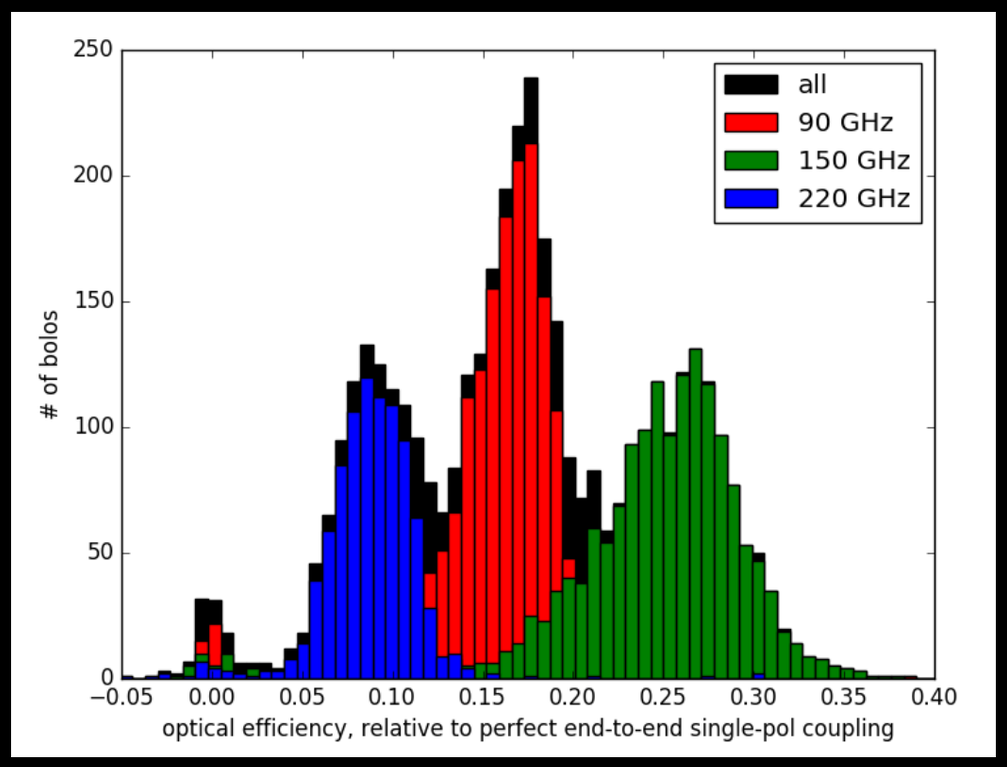

High saturation power ($P_{sat}$)
→ Large operating voltage bias
→ Extra noise power from readout

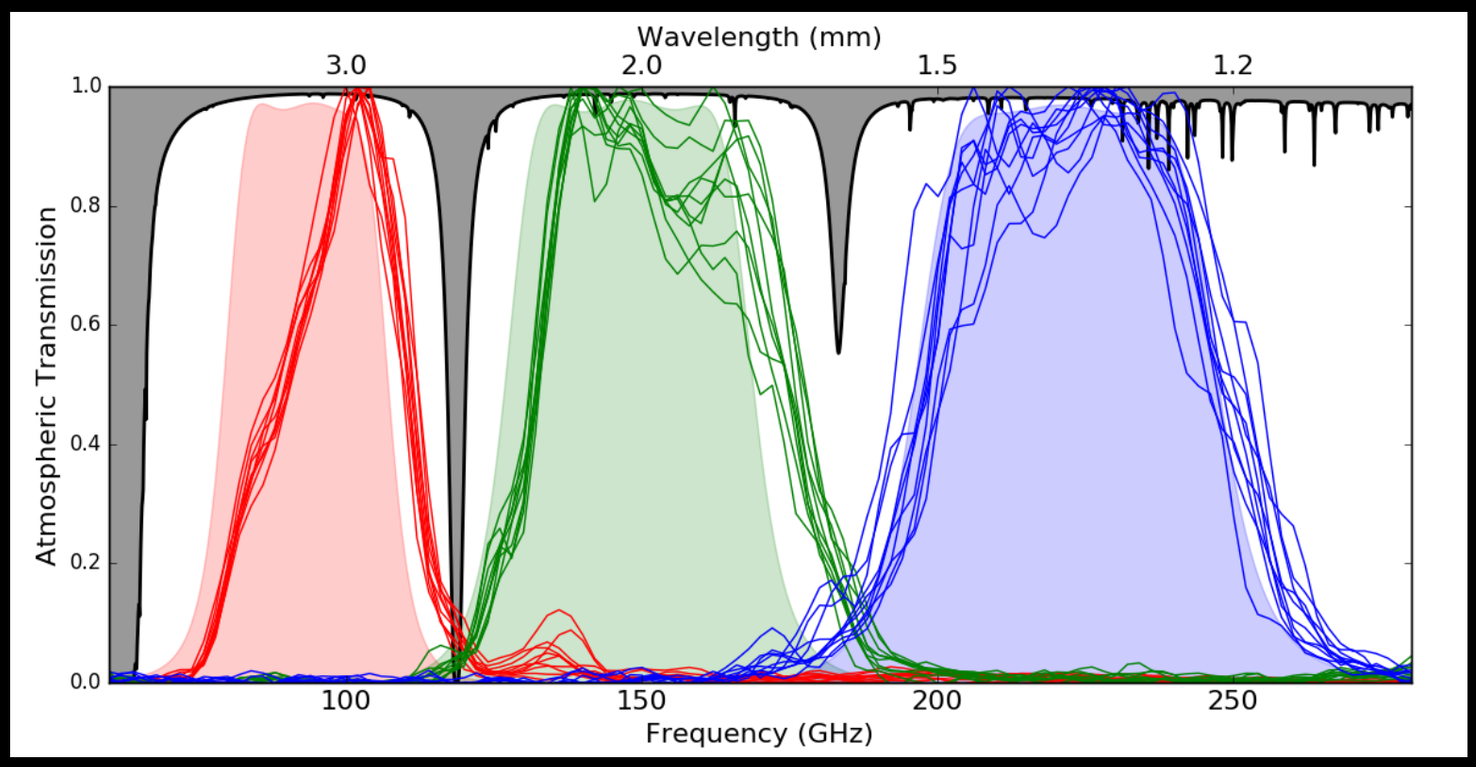
Detectors with optimized $P_{sat}$ to be installed.

# Optical Performance

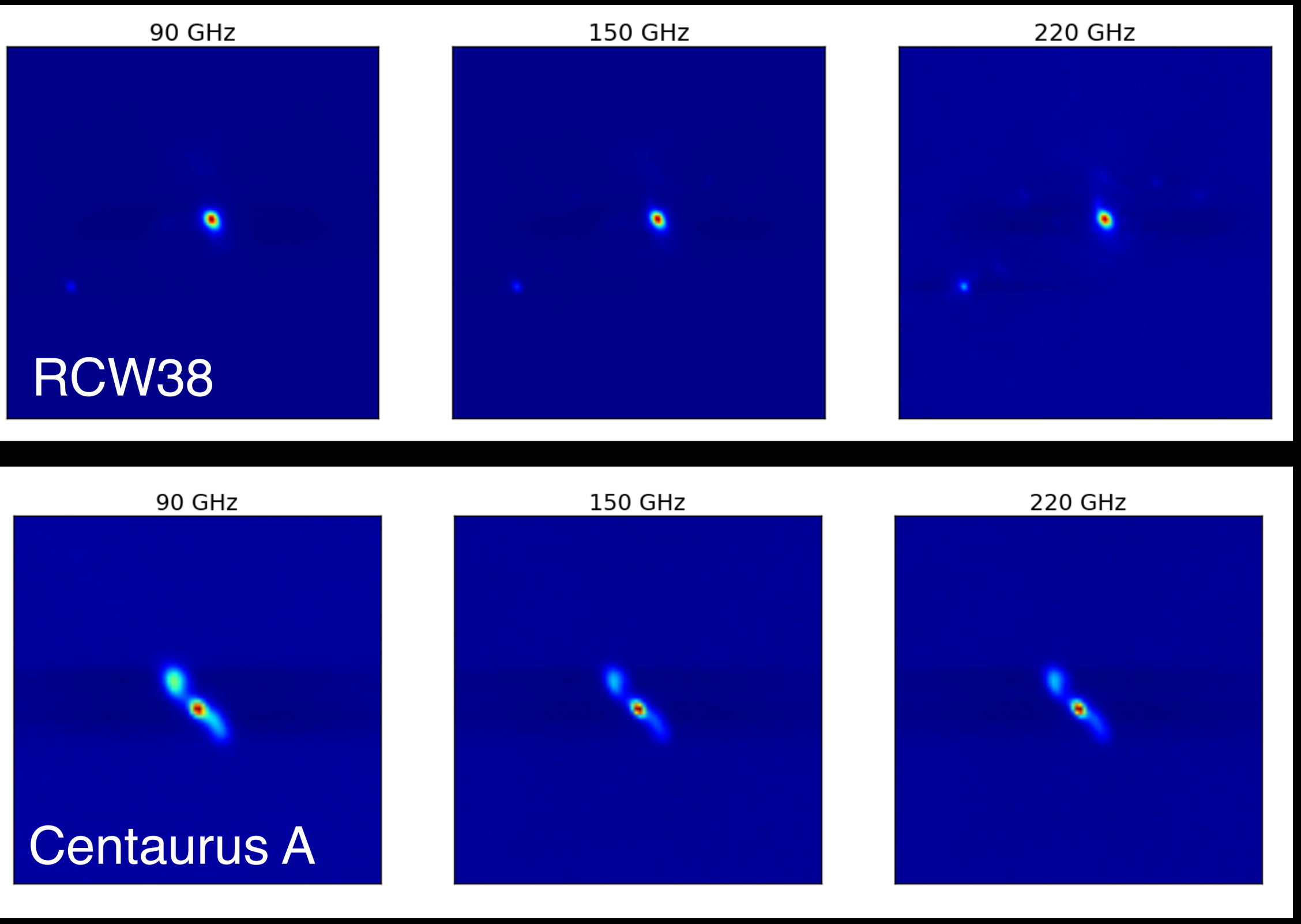
- Bands similar across all detector wafers
- Efficiency consistent with good detector efficiency (60-90% including lenslet)
- New AR coating of lenses will improve transmission in future



# Source Observations



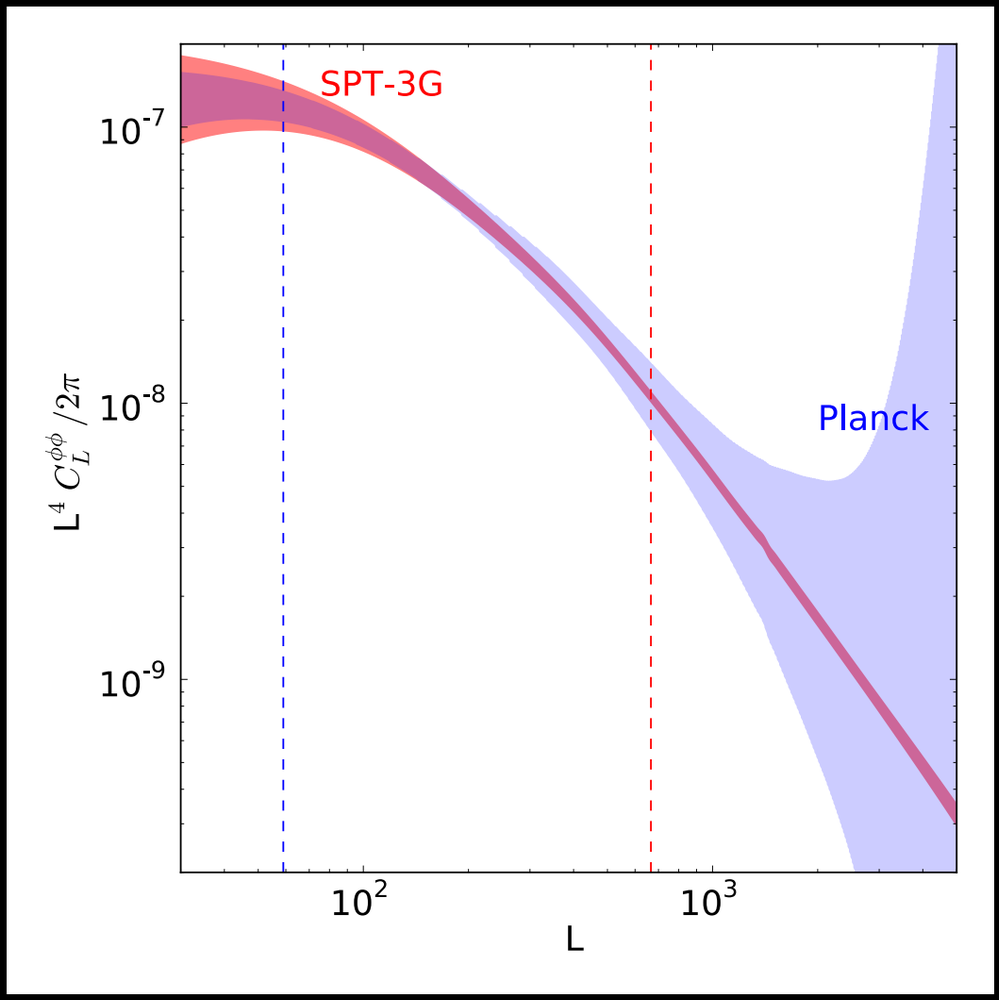
# SPT-3G Forecasts

2500 square degree survey for 4 years

| | 95 GHz | 150 GHz | 220 GHz |
|---|---|---|---|
| T (μK-arcmin) | 3.6 | 3.3 | 8.5 |
| P (μK-arcmin) | 5.1 | 4.7 | 12 |

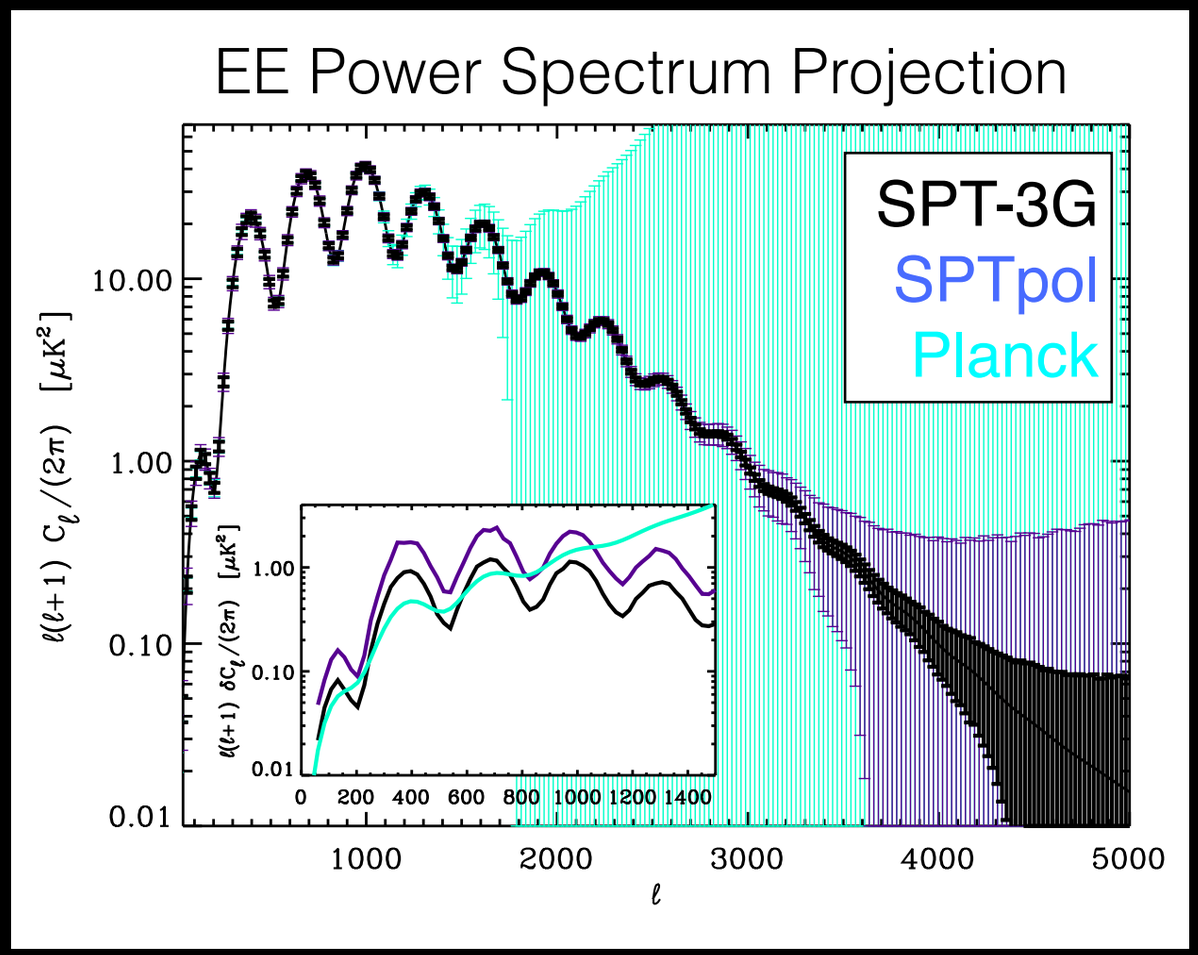
- Overlap with BICEP/Keck
- High S/N measurement of gravitational lensing B-modes
  - constrain sum of neutrino mass
  - de-lensing of B-mode power spectrum

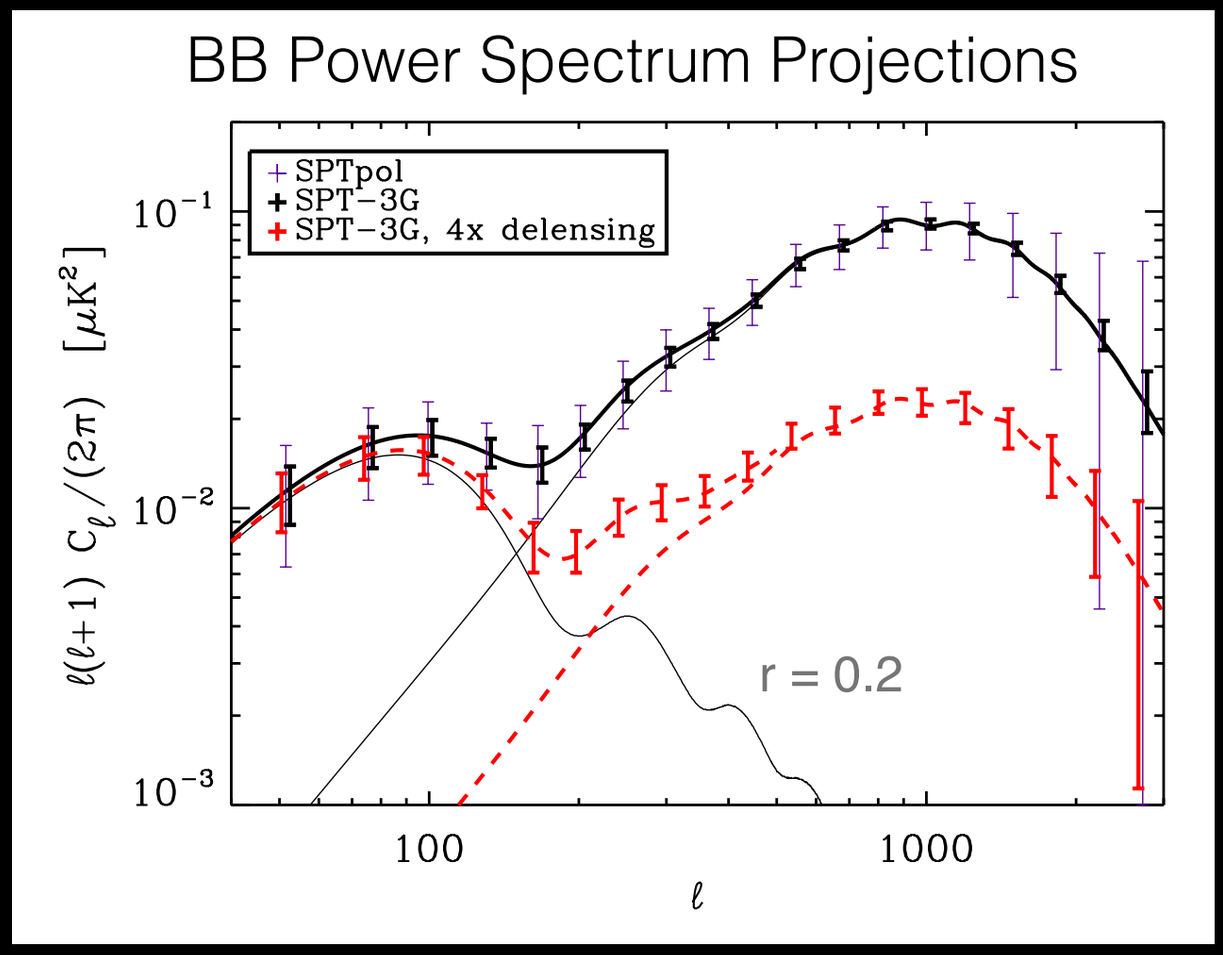
## Lensing Forecast




Benson 2014

# SPT-3G Projected Power Spectra




Benson 2014

## 2021 Projections

Priors from Planck + BOSS

| | |
|---|---|
| $\sigma(r)$ | 0.011 |
| $\sigma(\Sigma m_\nu)$ | 0.061 eV |
| $\sigma(N_{eff})$ | 0.058 |

# Summary

- SPT-3G installed on the telescope in early 2017
- Engineering and early science observations underway!
  - Optimizations in detectors, readout, and optics planned for installation in late 2017
- 4-year survey will map the polarization of the CMB with high-resolution
- Resulting data will be used to probe the neutrino sector and inflation